DARPA and the Microsystems Technology Office

Dr. John C. Zolper, Director

Dr. Dean Collins, Deputy Director

Young Faculty Award Workshop

November 16th, 2006

4 October 1957

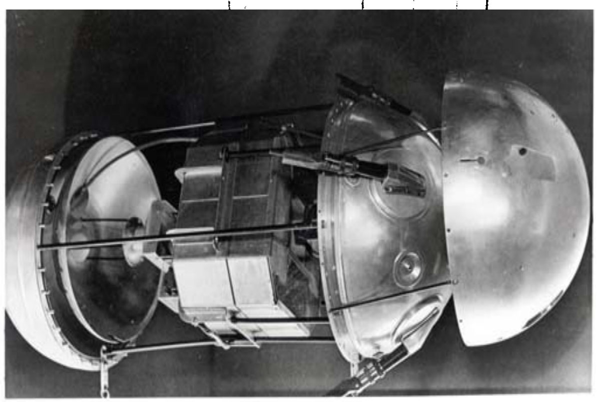
"All the News That's Fit to Print"

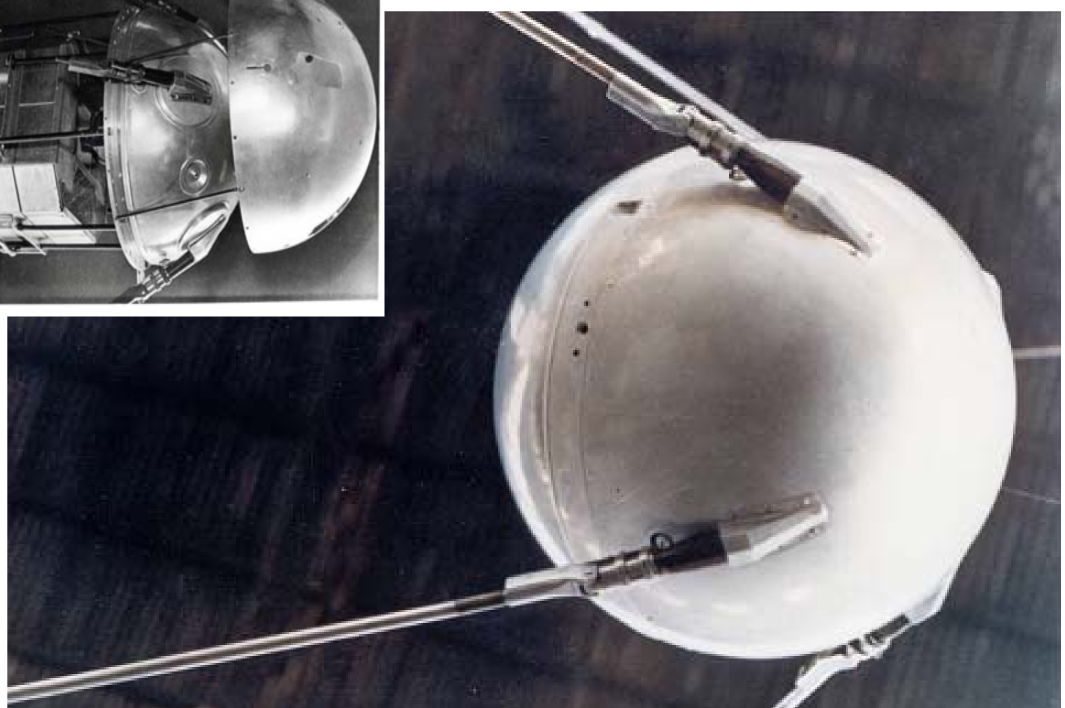
The New York Times.

LATE CITY EDITION
Cloudy and cool today and tonight. Mostly fair tomorrow.

VOL. CVII..No. 36,414. NEW YORK, SATURDAY, OCTOBER 5, 1957. FIVE CENTS

SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

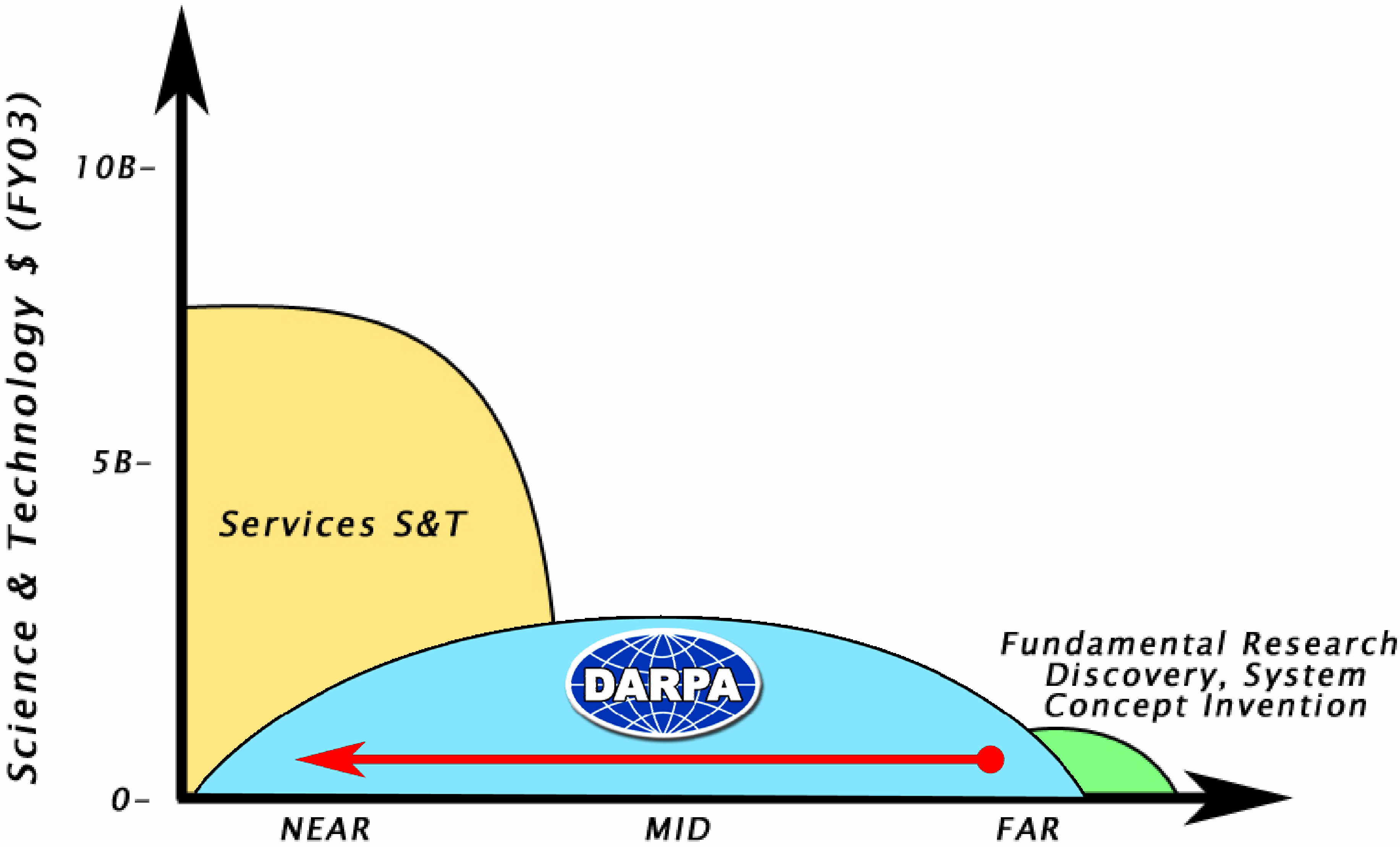




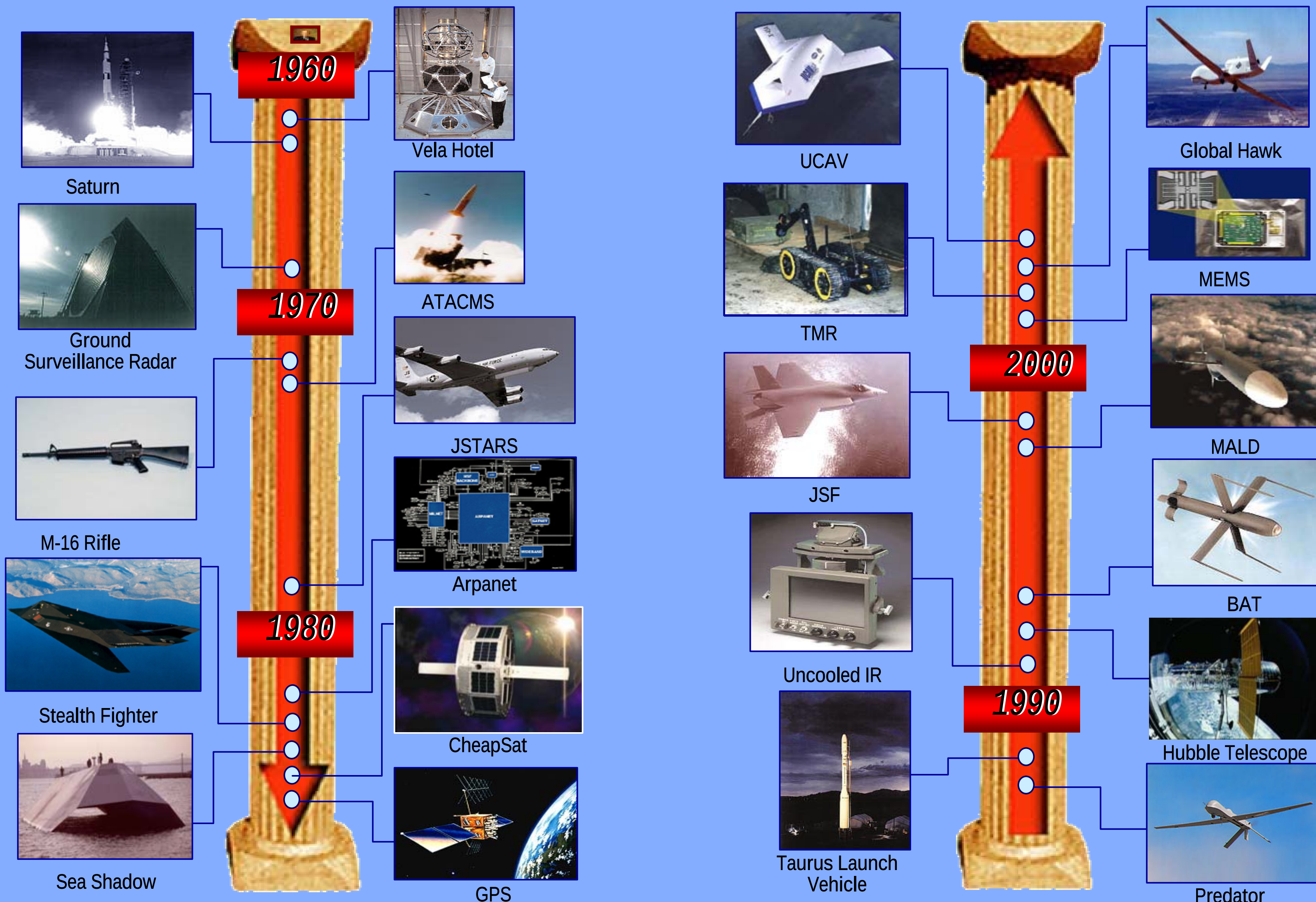
—Dallas News Staff Photo.

SIGNALS FROM THE SATELLITE
Ham operator Roy Welch of Dallas, seated, plays a tape-recorded signal from the Russian space satellite for fellow hams at the State Fair of Texas. Welch recorded the signals on a receiver at his home.

DARPA's Role in Science and Technology



DARPA Accomplishments



DARPA Organization

Director, Tony Tether
Deputy Director, Bob Leheny

Tactical Technology
Steve Welby
Steve Walker

- Air/Space/Land/Sea Platforms
- Unmanned Systems
- Space Operations
- Laser Systems
- Precision Strike

Information Exploitation
Bob Tenney
Mark Davis

- Sensors
- Exploitation Systems
- Command & Control

Strategic Technology
Dave Honey
Larry Stotts/Brian Pierce

- Space Sensors/Structures
- Strategic & Tactical Networks
- Information Assurance
- Underground Facility Detection & Characterization
- Chem/Bio Defense
- Maritime Operations

Defense Sciences
Steve Wax
Brett Giroir/Barbara McQuiston

- Physical Sciences
- Materials
- Biology
- Mathematics
- Human Effectiveness
- Bio Warfare Defense

Information Processing Technology
Charlie Holland
Barbara Yoon

- Cognitive Systems
- High Productivity Computing Systems
- Language

Microsystems Technology
John Zolper
Dean Collins

- Electronics
- Photonics
- MEMS
- Algorithms
- Integrated Microsystems

DARPA Transition Paths

DARPA → Industry Develops Products → Service Production

Components, small systems

DARPA → Svc S&T / CTD → SDD → LRIP → Production

Concept and Technology Development (MS A)

System Development and Demonstration (MS B)

Low Rate of Initial Production (MS C)

Other systems innovations

DARPA → SDD → LRIP → Production

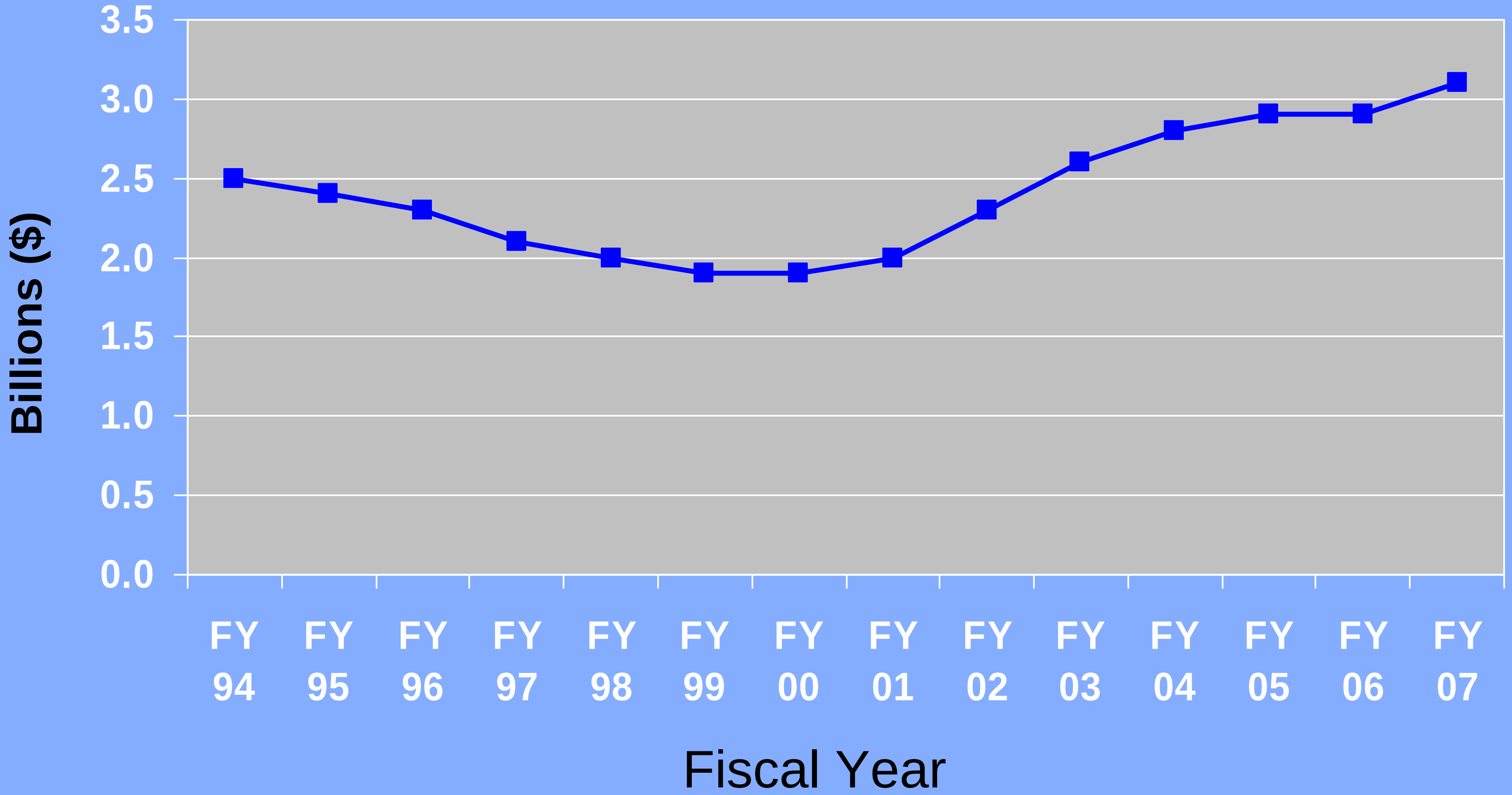
POM submit

DARPA's Strategic Thrusts

Investments Today for Future Capabilities

- **Robust, Secure Self-Forming Tactical Networks**
- **Detection, Precision ID, Tracking & Destruction of Elusive Targets**
- **Networked Manned & Unmanned Systems**
- **Urban Area Operations**
- **Location and Characterization of Underground Structures**
- **Assured Use of Space**
- **Cognitive Systems**
- **Bio-Revolution**
- **Core Technologies (Materials / Electronics / Information Technology)**

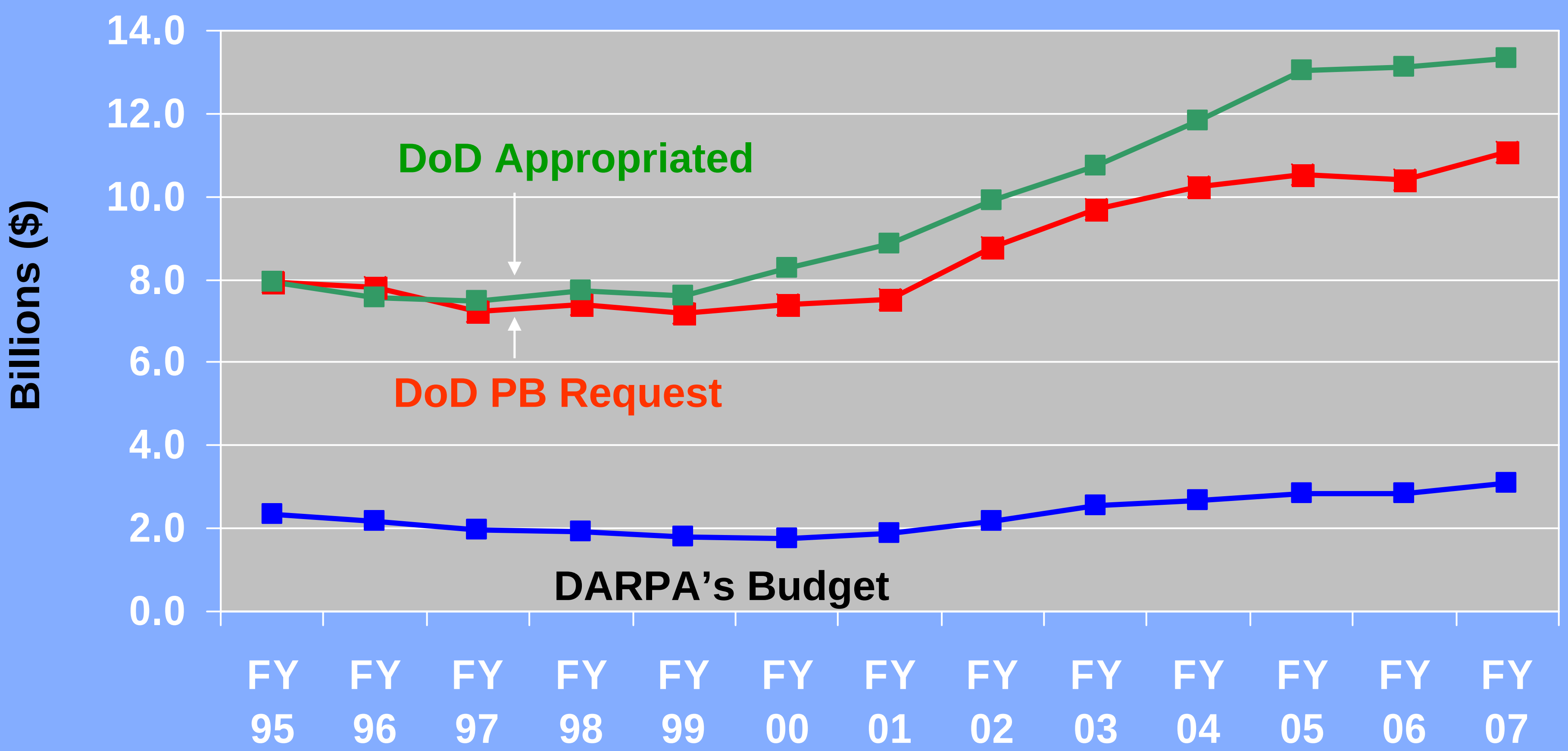
DARPA Budget ($B)



Note: Amounts reflected are appropriated funds

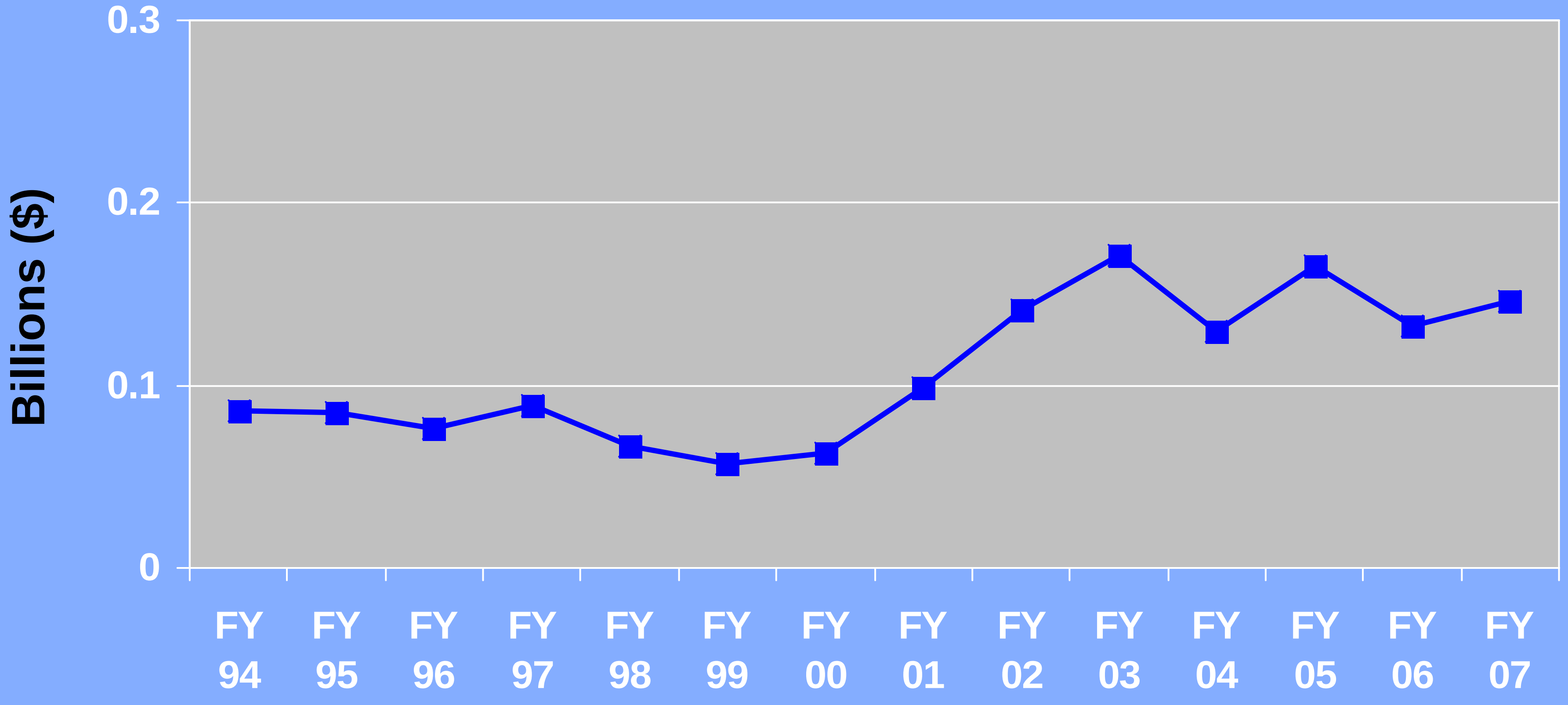
DoD S&T Budgets and DARPA Budget ($B)

Total of all 6.1, 6.2 and 6.3 budget activities



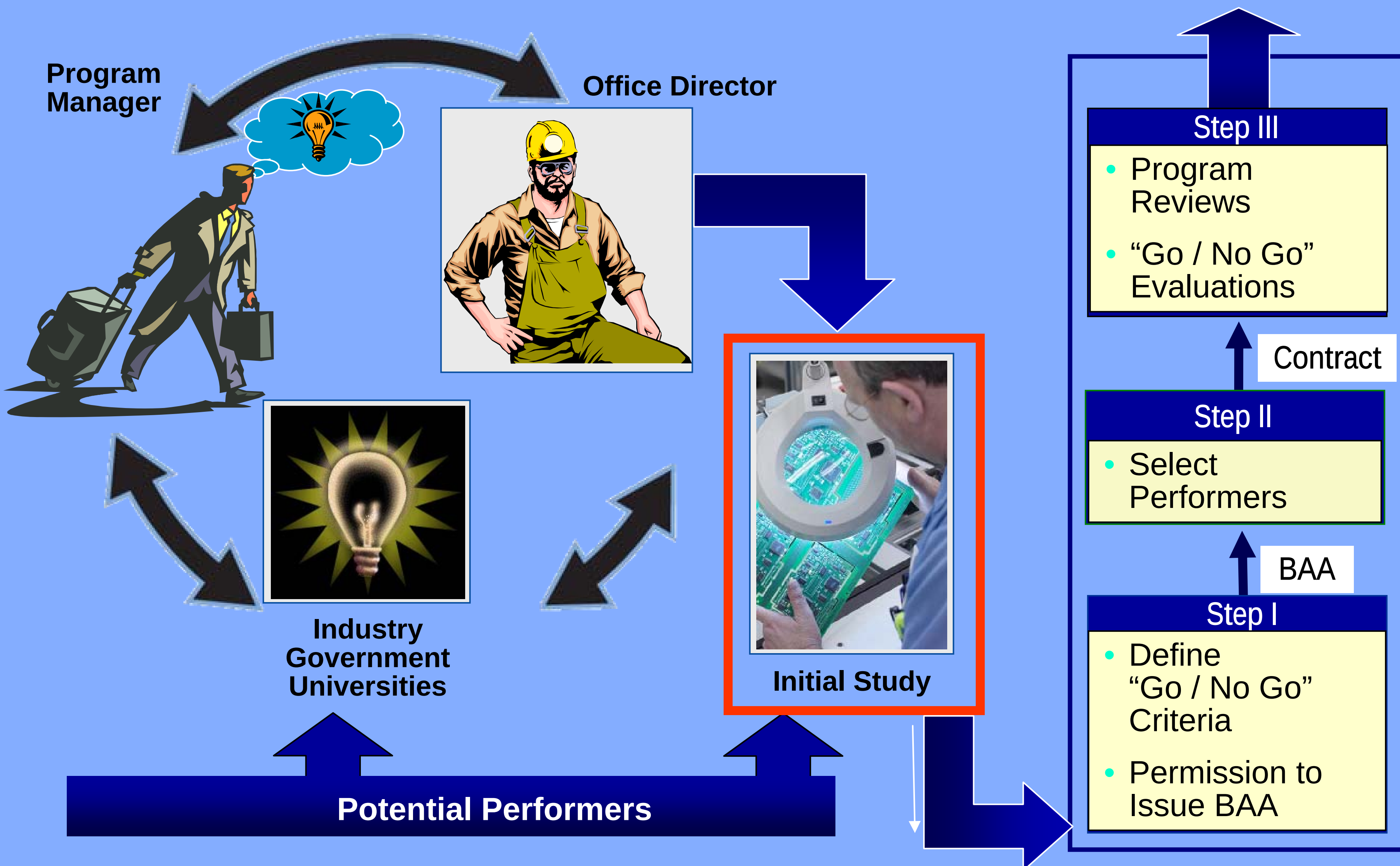
DARPA Basic Research Funding ($B)

Budget Activity 6.1 ("University" funding)



Unfettered "university-like" science research without specific applications in mind

DARPA New Initiative Process



What makes a DARPA Program: The Heilmeier Criteria

1. **What are we trying to do? What is the problem we are trying to solve?**

2. **How is it done today, and what are the limitations of current practice?**

3. **What is new in our approach, and why do we think it will be successful? What gives evidence that it will work?**

4. **Assuming we are successful, what difference does it make?**

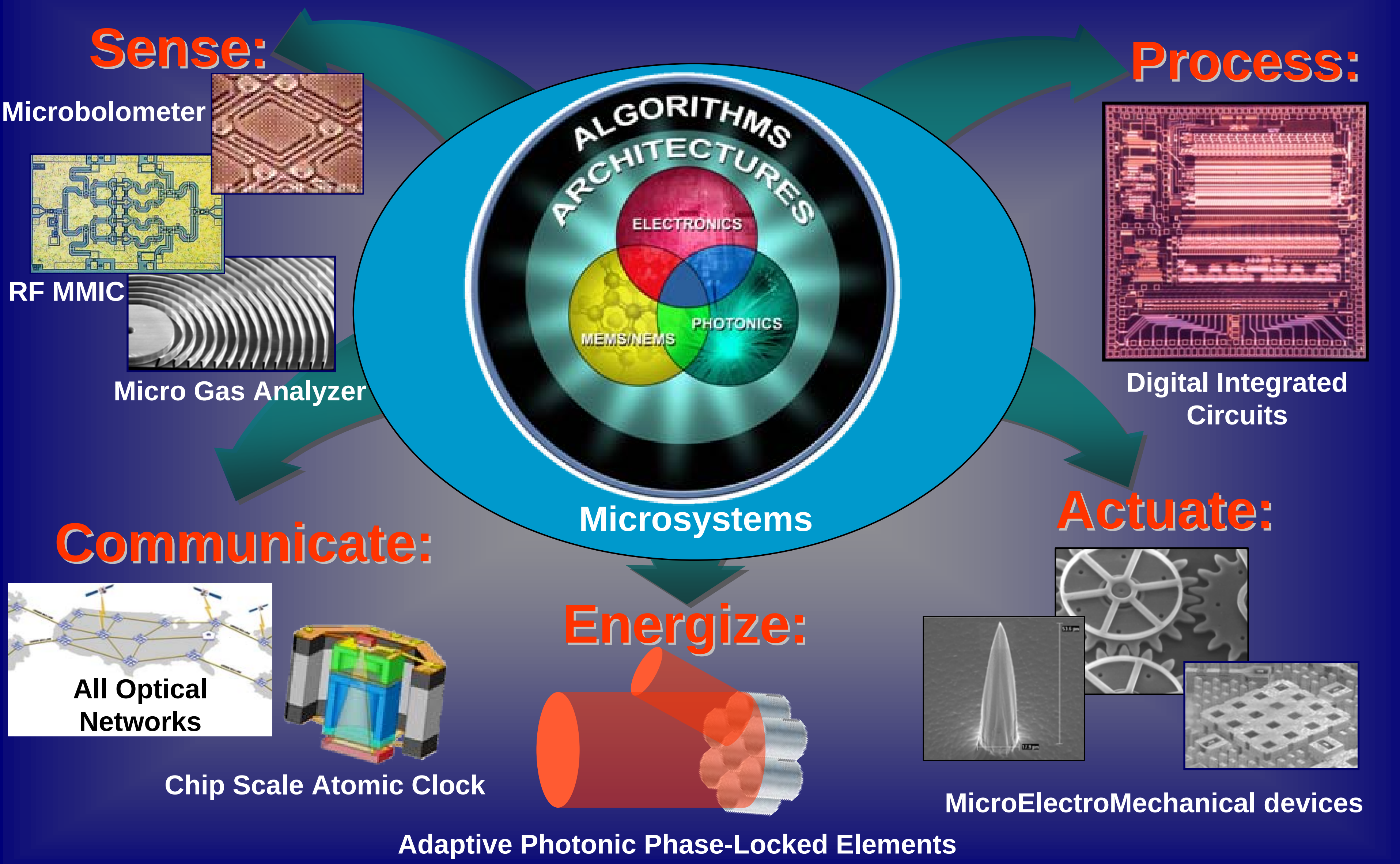
5. **How long will it take, how much will it cost, and what are the mid-term and final exams?**

Dr. George Heilmeier
DARPA Director, 1975-1977

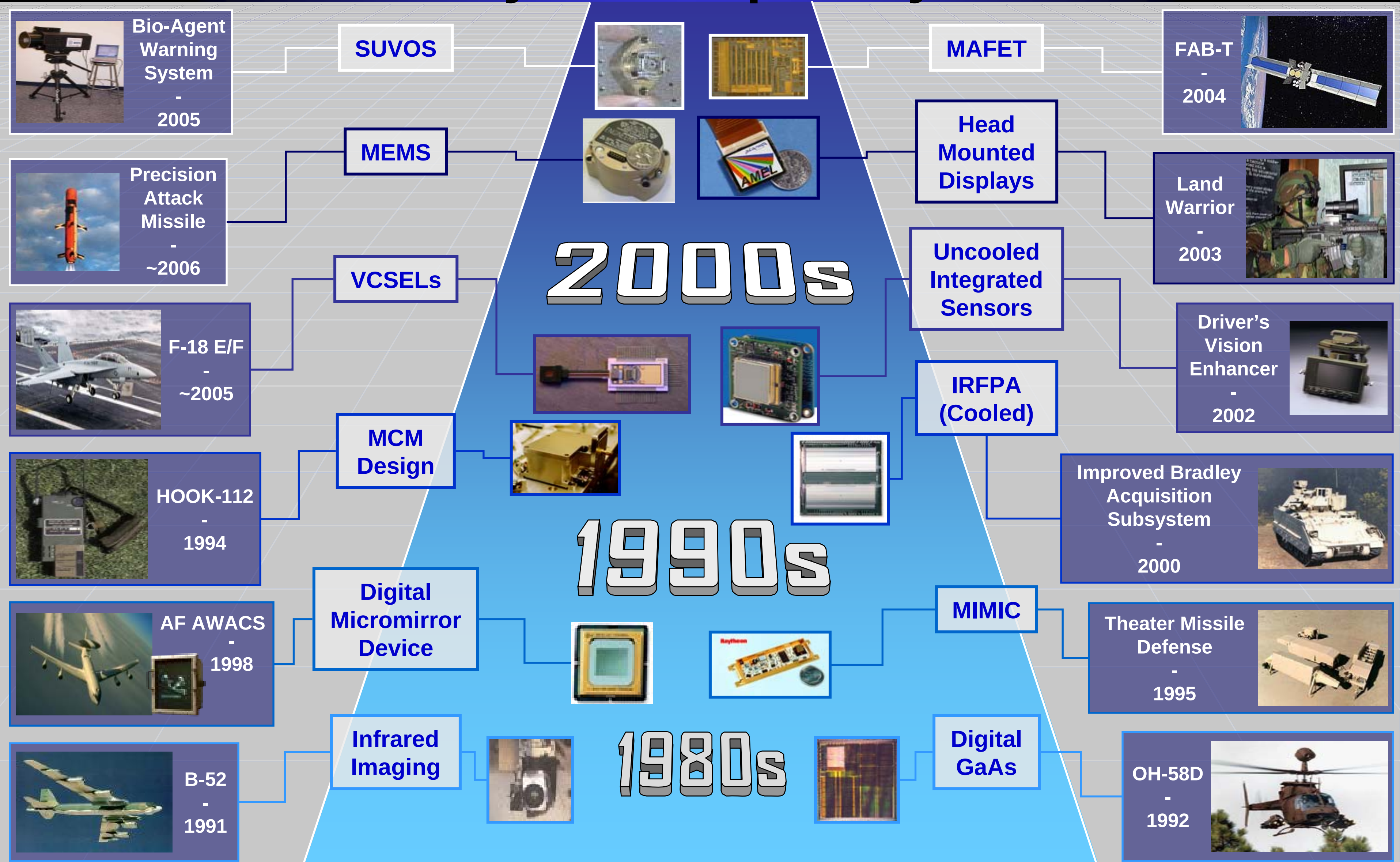
MTO's Mission

Exploit breakthroughs in materials, devices, circuits, and mathematics to develop beyond leading edge Microsystems components with revolutionary performance and functionality to enable new platform capability for the Department of Defense.

Microsystems Technology Office



MTO Components Have Enabled System Capability



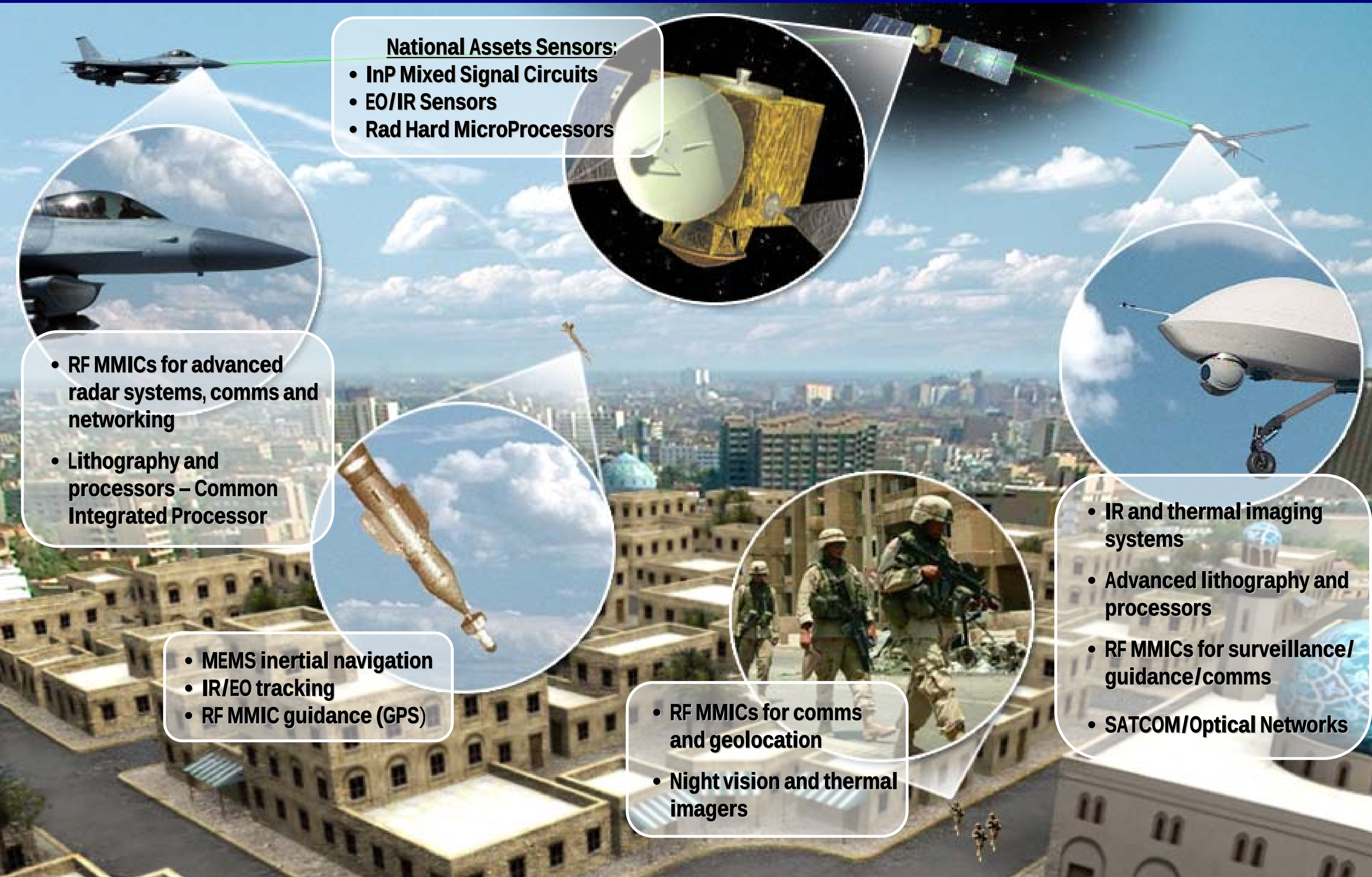
Microsystems Technologies Impact on Marine Corps Systems

The individual soldier's load is cumbersome, but advances in microsystems have enabled enhanced capabilities in a reduced overall form factor

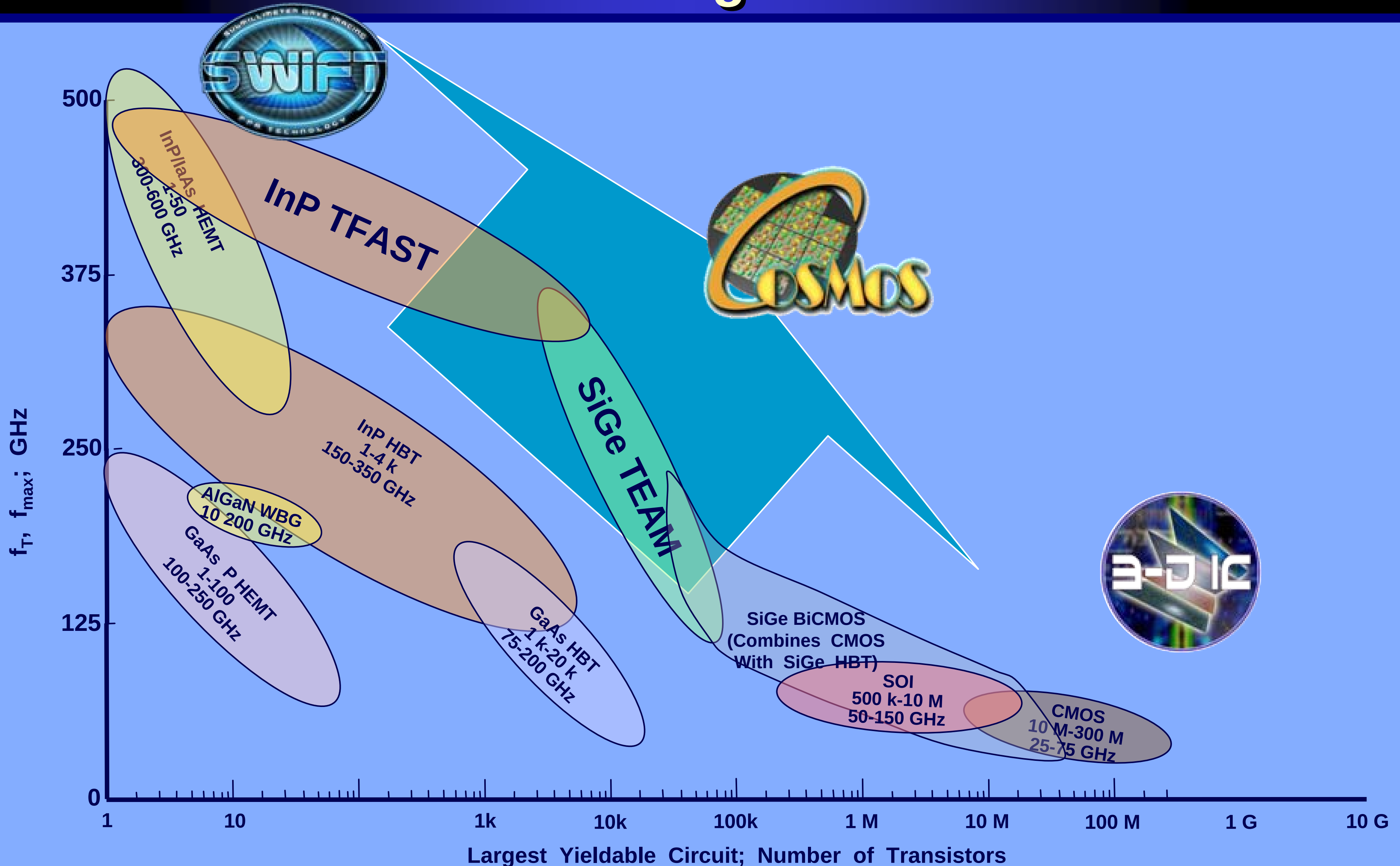
Improved Performance

Reduced Package Size

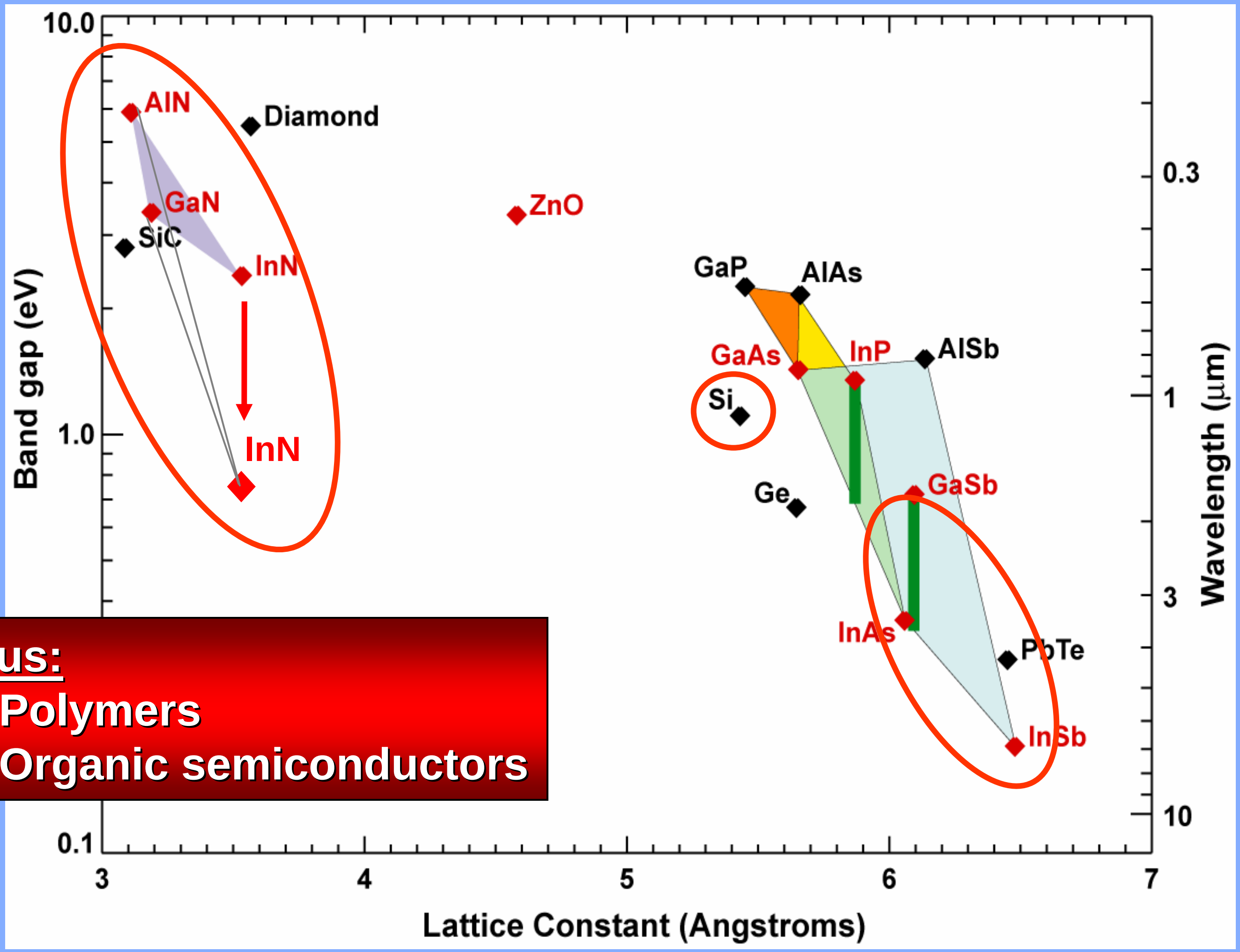
Microsystems in the Current Fight



Driving Device Performance and Integration



Exploiting Emerging Materials



Plus:
- Polymers
- Organic semiconductors

… and getting more out of old favorites!

Exploiting Photonics Technology

Bandwidth

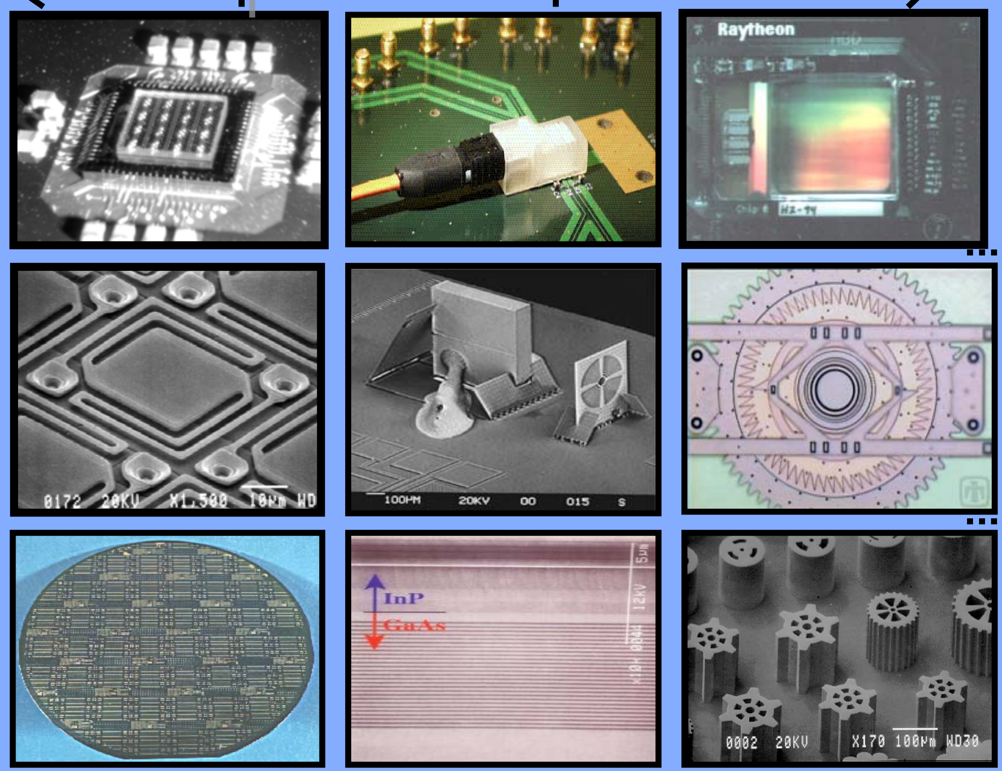
Zero Crosstalk

Sensing

Application Pull

MTO

Technology Push



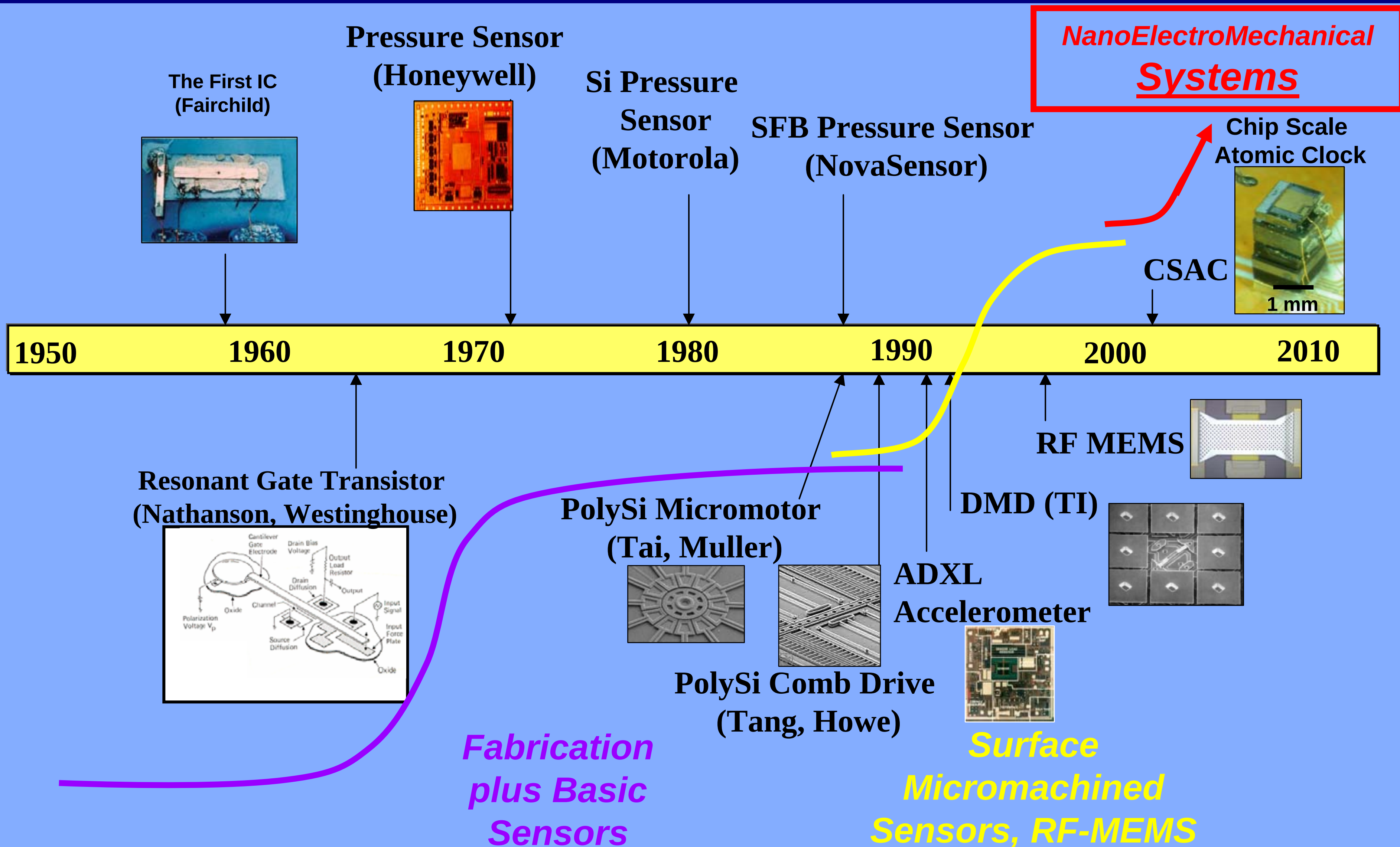
Module

Device

Fabrication

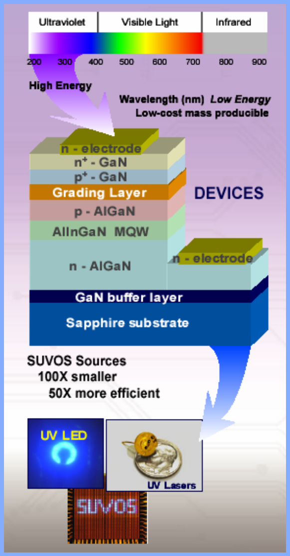
Materials

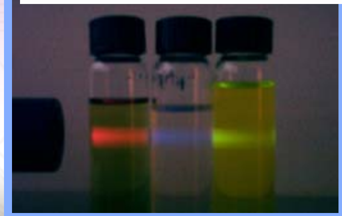
Opening MEMS Frontiers

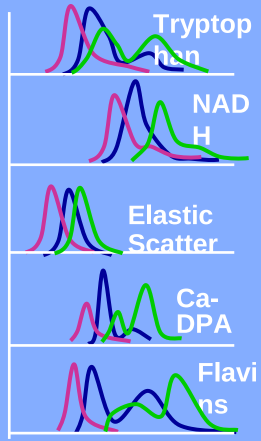


Modified from a slide from
YC Tai, Caltech

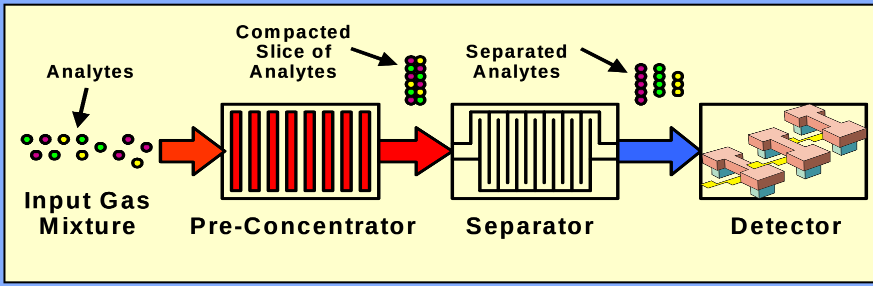
Chem/Bio Sensing

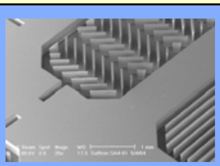






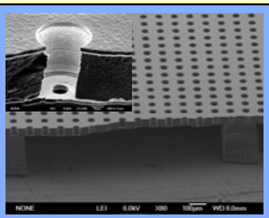
Semiconductor Ultra Violet Optical Sources (SUVOS)





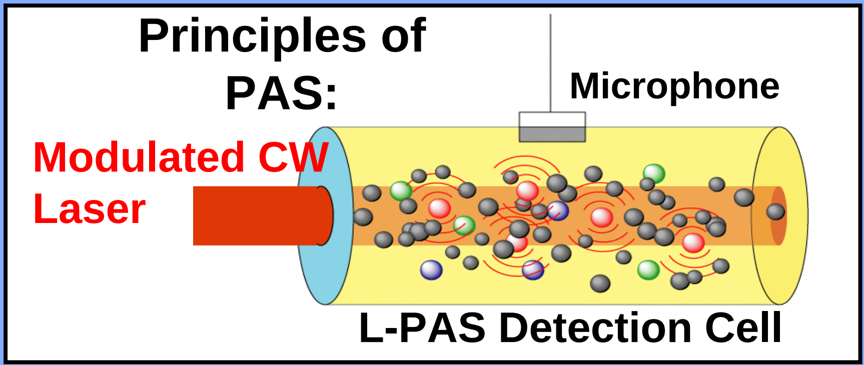
Chemical preconcentration nanostructures

Micromachined chromatography columns



Ion Mobility Mass Spec

Micro Gas Analyzer (MGA)

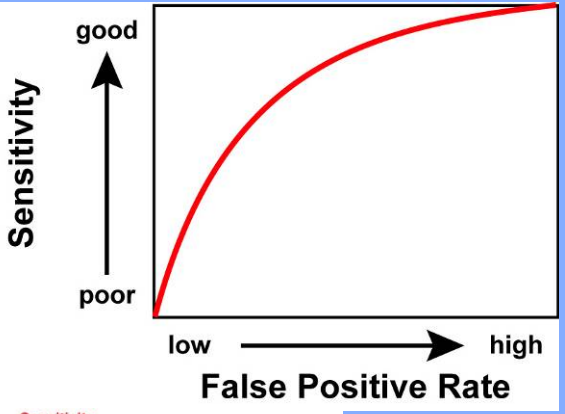


Laser Photo Acoustic Spectroscopy (L-PAS)

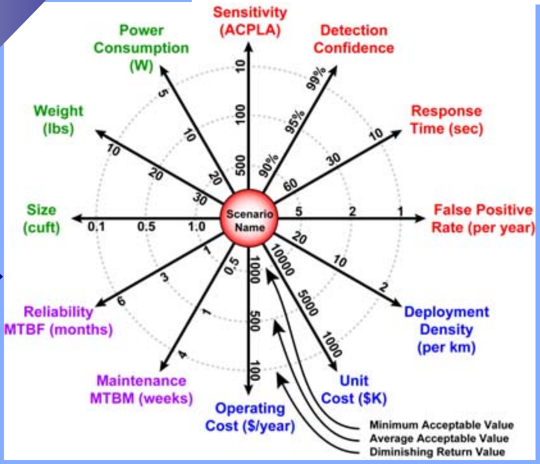
Chemical and Biological Sensor Standards Study (CBS³) Summary
(http://www.darpa.mil/mto/publications/index.html)

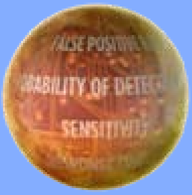
- Study Motivation
  - Lack of clear metrics for evaluation of Chemical and Biological sensors
  - Inadequacy in Chemical and Biological sensor testing protocols is affecting sensor development
- Study Goal: *Define metrics and protocols for evaluation of chemical and biological sensors*
  - Focus on atmospheric, detect-to-warn DoD missions
  - Remain technology agnostic
  - Define relevant CONOPS scenarios
- Identified Key Sensor Metrics
  - Sensitivity
  - Probability of detection
  - False positive rate
  - Response time
- Identified Other Important Attributes
  - Unit Cost
  - Operating Cost
  - Power Consumption
  - Reliability
  - Size
  - Weight
  - Maintenance

Captured by Receiver Operating Characteristic (ROC) Curve



Spider Chart:
allows comparison
of alternative approaches





Office Initiatives

- Intelligent Integrated Microsystems: Nurturing the dialog between applied mathematics, signal processing, and hardware developers to push data analysis into the front end sensor

- Complex Systems Architectures: Examining constructs for optimizing complex interactions of hardware and control to identify new Microsystems opportunities

- Airplane-on-a-Chip: Microsystems grand challenges for integration, data processing, navigation, and guidance

- Young Faculty Award: Fostering the next generation of academic component research to address DoD problems

Path towards Intelligent Microsystems

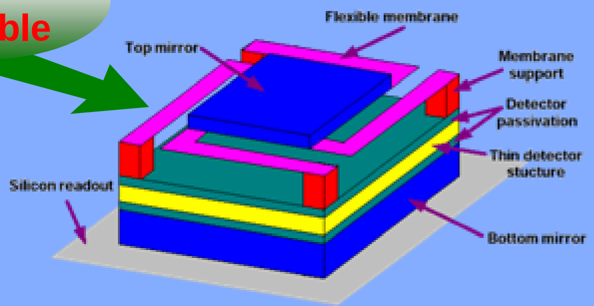
Increasing Capability

- **Intelligent:** High level of autonomy with the ability to reason and learn with time
- **Adaptive:** Some degree of autonomy to self optimize, test, or monitor. Able to change mode of operation.
- **Reconfigurable:** Predefined, deterministic set of operating parameters that can be selected externally.
- **Static:** Fabricated to design specifications with fixed performance.

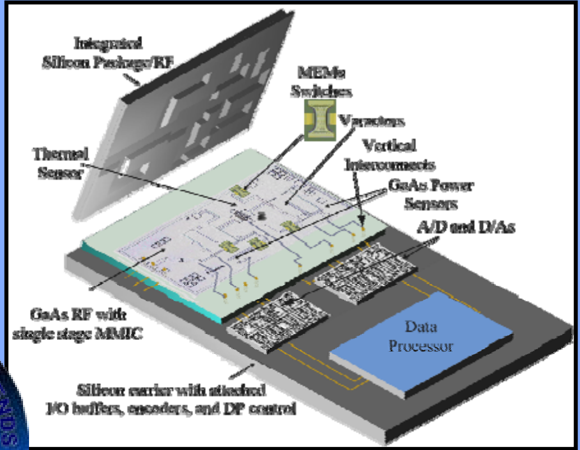
Current Systems

Reconfigurable Microsystems

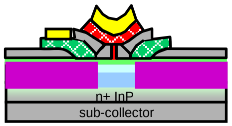
Each Pixel tunable



AFPA
ADAPTIVE FOCAL PLANE ARRAY
"Own the Night"



INTELLIGENT RF FRONT-ENDS
DARPA-MTO



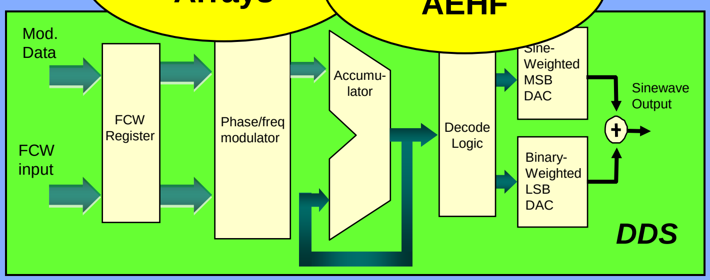
500 GHz HBTs

Transformational Comms

SBR/Phased Arrays

MILSTAR AEHF

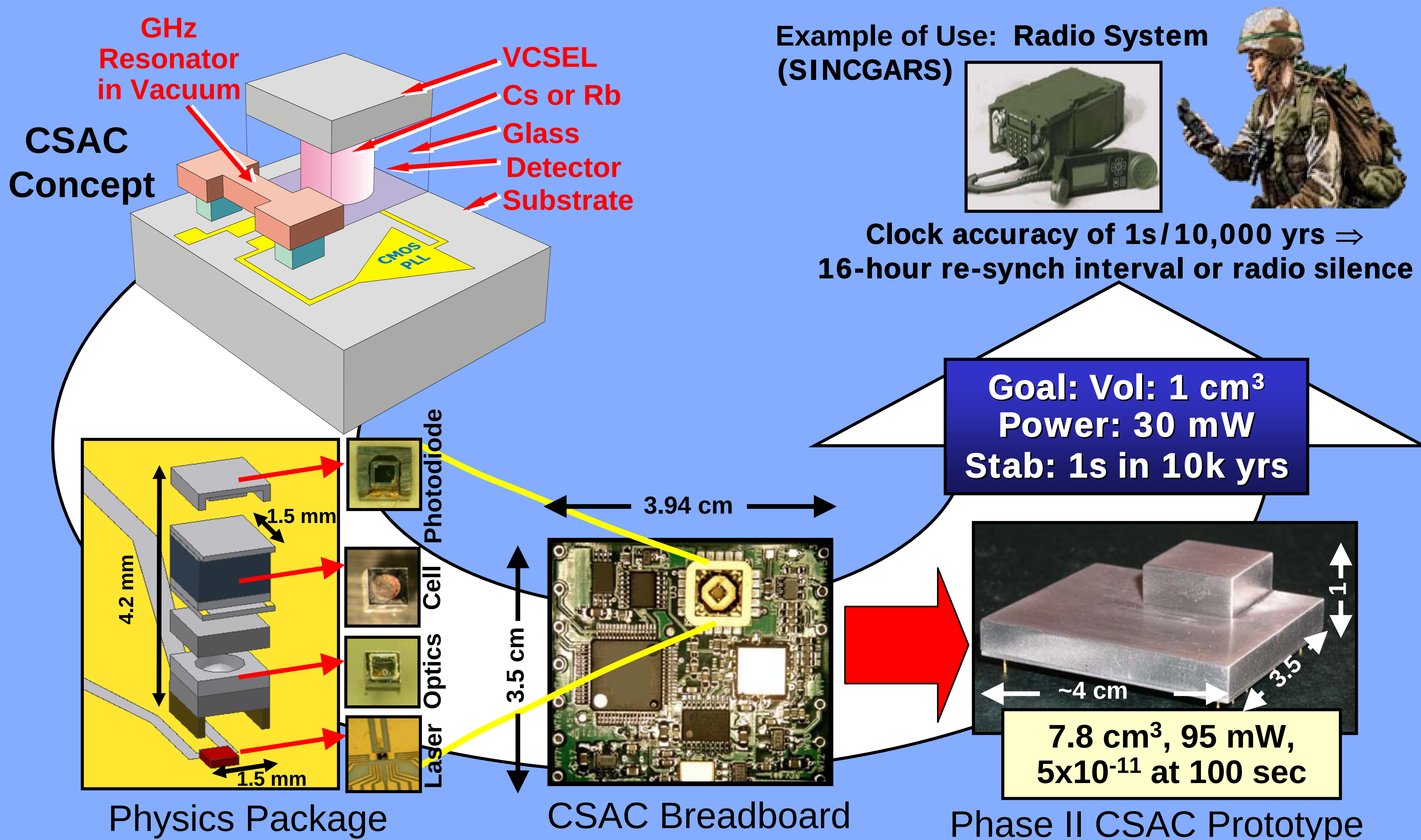
MILSTAR AEHF



TFAST
Technology for Frequency Agile Digitally Synthesized Transmitters

Microwave Digital Synthesizers: Digitally controlled phase, amplitude, and frequency modulation

Integrated Microsystem:
Chip Scale Atomic Clock

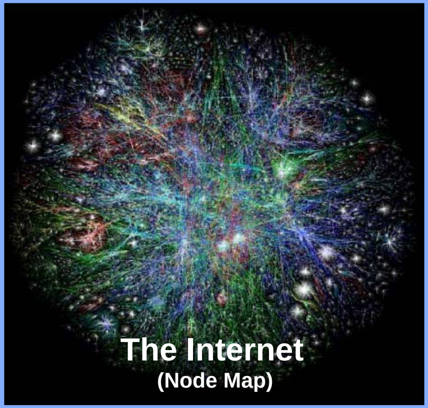


Precision Time for Every Radio and Network Node

Engineering Complex Systems (more than just the components)

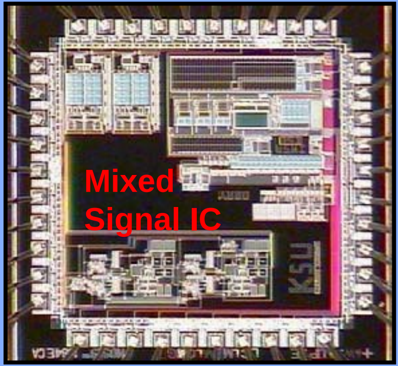

A Swiss watch

Complicated: Many pieces, but the whole can be reassembled from its parts. A key flaw brings the entire system to a halt.


The Internet
(Node Map)


Ecosystems


H5N1 Propagation in Russia


Mixed Signal IC

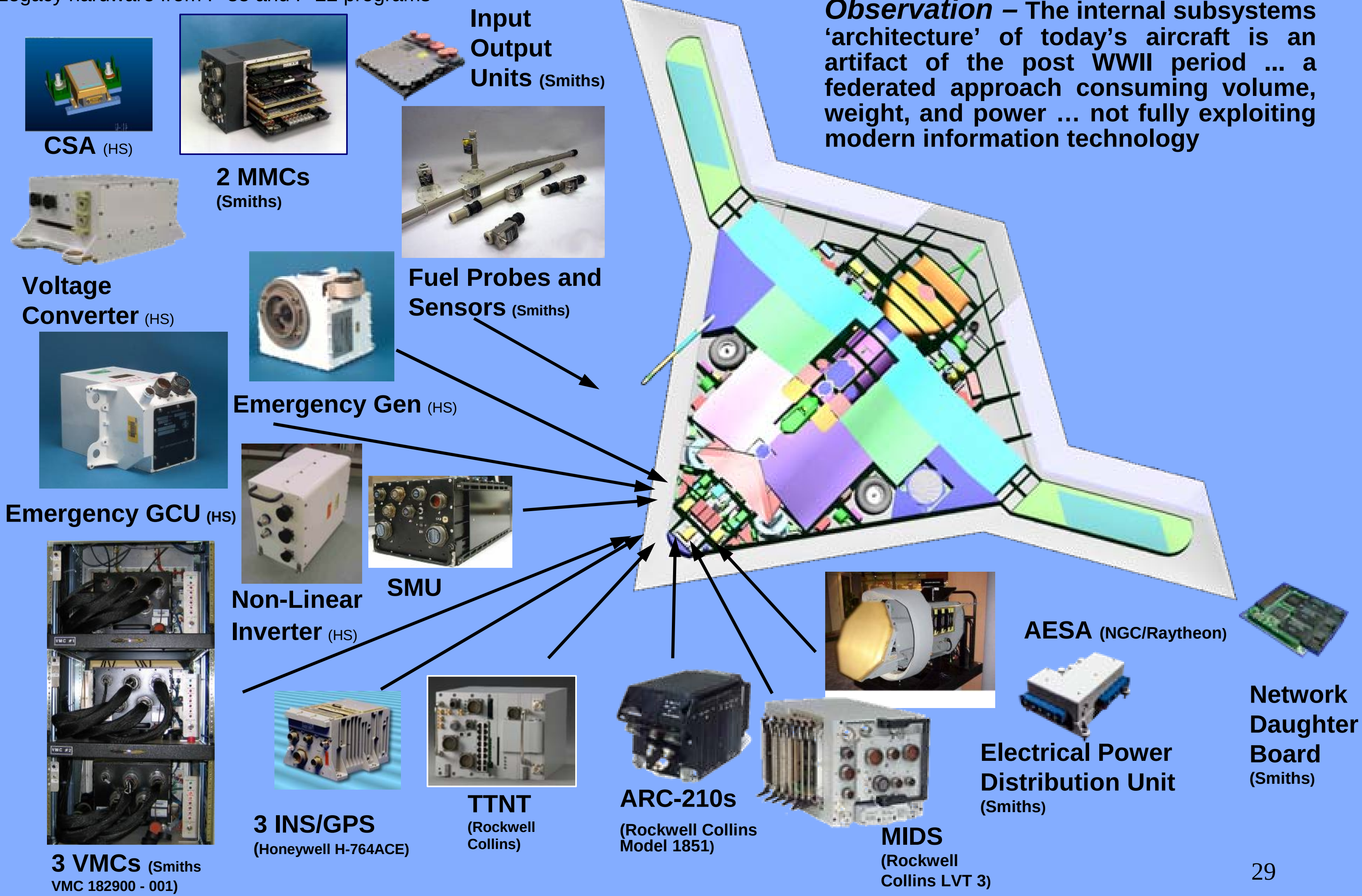
Complex: Overall performance can not be represented via reduction to "sum of the part". Complex systems are adaptive, self-organizing, and emergent.

What Microsystems that will Produce Complex Systems at are Robust, Adaptable, and High Performance?

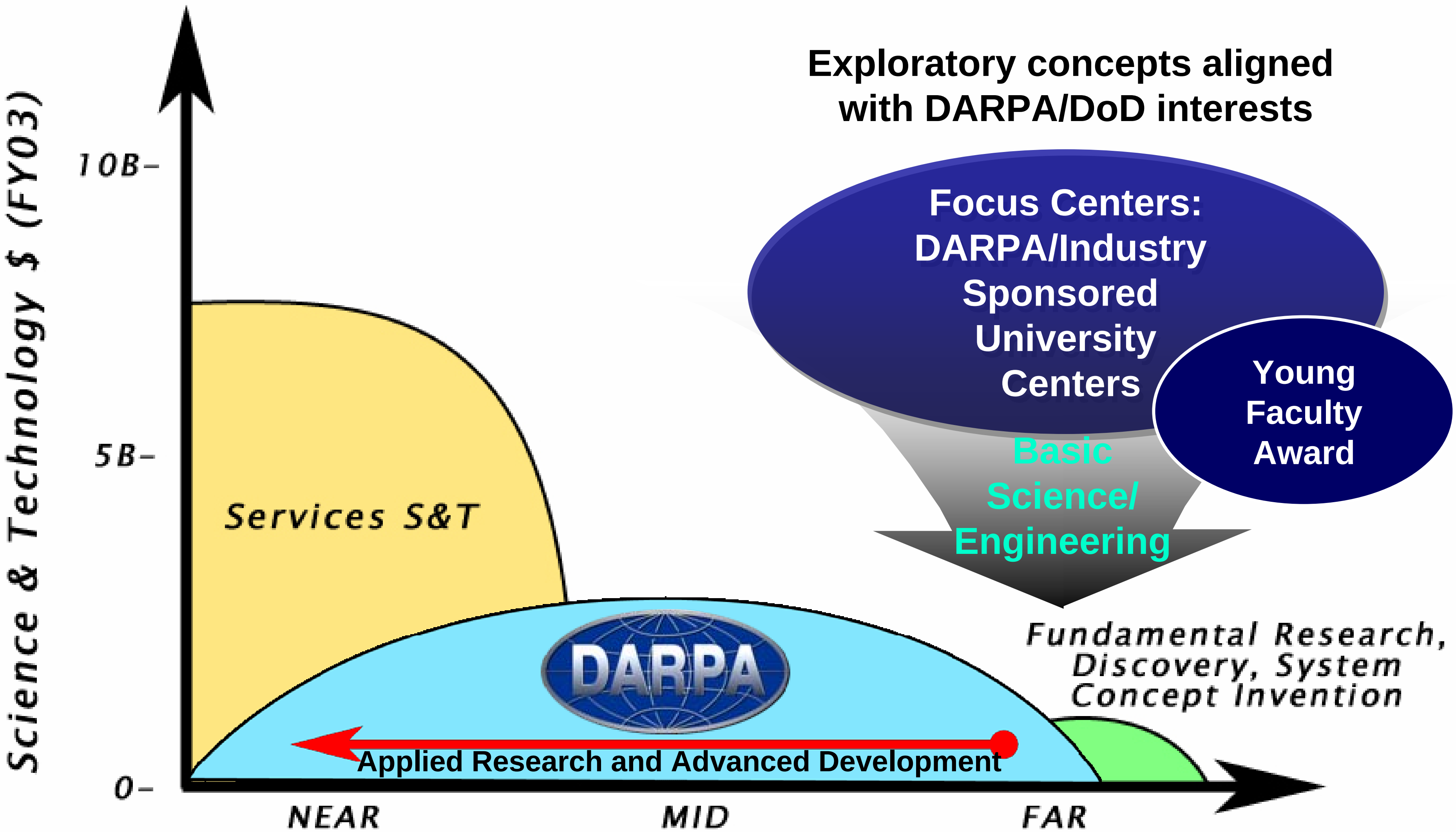
Avionics Today … Avionics Tomorrow?

Legacy hardware from F-35 and F-22 programs

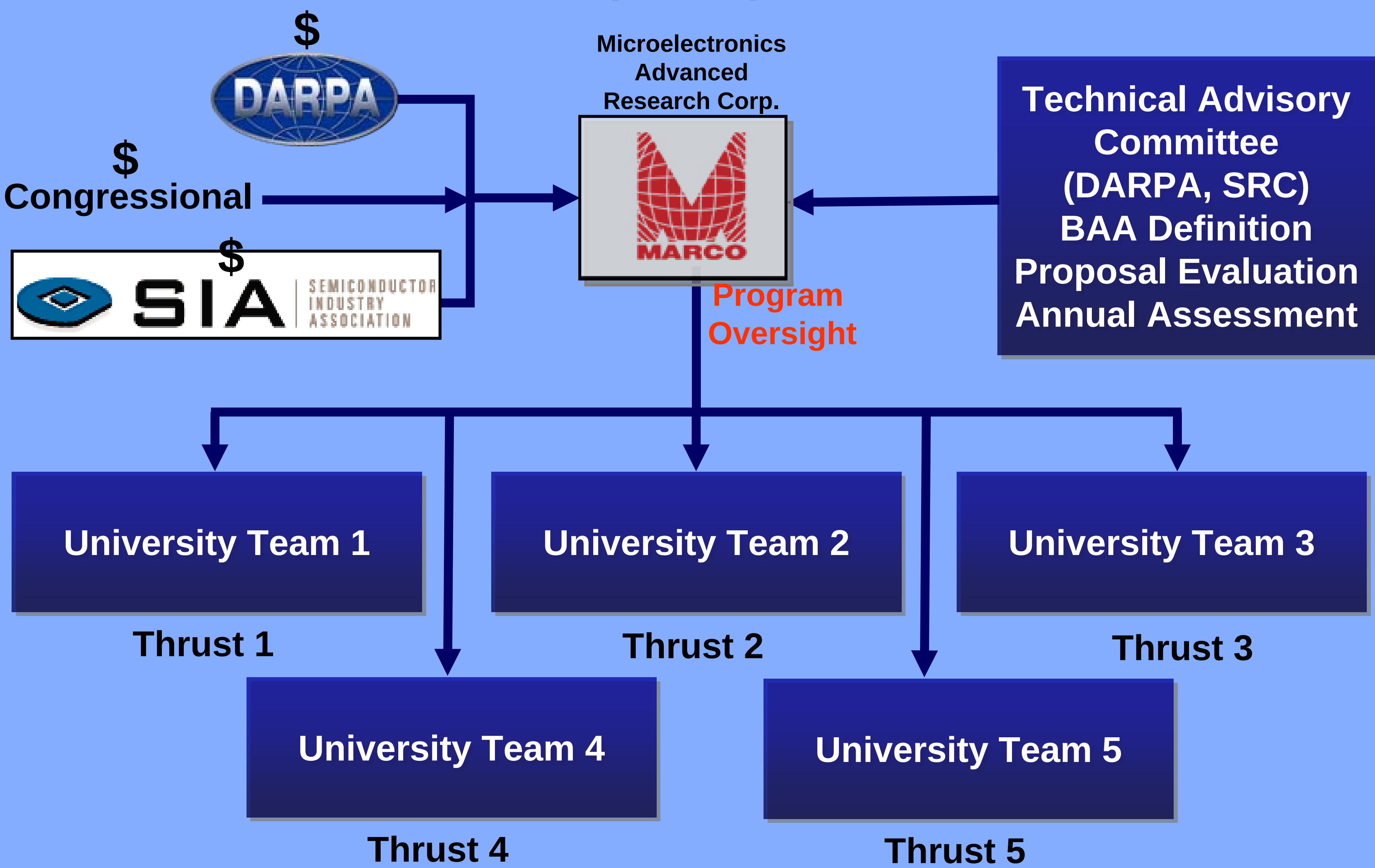
Observation **– The internal subsystems 'architecture' of today's aircraft is an artifact of the post WWII period … a federated approach consuming volume, weight, and power … not fully exploiting modern information technology**



DARPA's Role in Science and Technology



Microelectronics Focus Center Research Program (FCRP)



Focus Center Research Program

MARCO

Sponsors:

SIA Semiconductor Industry Association

- AMD
- Analog Devices
- Conexant
- Cypress
- IBM
- Intel
- LSI Logic
- Micron
- Motorola
- National
- TI
- Xilinx

semi

- Air Products
- Applied Materials
- Cadence
- Novellus
- Teradyne

Department of Defense

DUSD (LABS)

DARPA

GSRC – System Design & Test Focus Center

Prof. Jan Rabaey

The University of California at Berkeley is the lead university for the System Design and Test Focus Center (Gigascale System Research Center--GSRC) and Prof. Jan Rabaey the center's director. The Design and Test Center's research agenda addresses the design, verification, and test of complex, heterogeneous (embedded) systems-on-a-chip/ package, covering the complete spectrum from system specification to implementation on emerging circuit fabrics.

C2S2 – Circuit Design & Test Focus Center

Prof. Rob Rutenbar

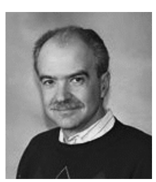
The Focus Center for Circuit and System and Solutions (C2S2) is led by the Carnegie Mellon University. Professor Rob Rutenbar is the center director. The center's research focuses on inventing the circuit techniques and system concepts needed for integrating heterogeneous devices as well as converting end-of-roadmap devices and the promising post-CMOS devices into robust performance across the most diverse range of applications.

IFC – Interconnect & Optoelectronics Focus Center

Prof. James Meindl

The leadership for the Interconnect Focus Center (IFC) is based at the Georgia Institute of Technology. Professor James Meindl is the focus center director. The center's research teams examine high conductance nanoscale electrical interconnects, optical interconnects that will scale to meet the needs of future gigascale silicon electronic systems, novel thermal management solutions and interconnect driven circuit and system design.

NST – NanoScale Devices Focus Center



Prof. D. Antoniadis

The Massachusetts Institute of Technology is the lead university for the Nanoscale Devices Focus Center (NST) and Prof. Dimitri Antoniadis its director. This center will push CMOS scaling to its ultimate limit through advanced FETs incorporating novel materials and explore new frontier devices such as nanotube devices, molecular devices and spin based FETs, with due emphasis on coupling experiment with theoretical modeling and simulation .

FENA – NanoScale Materials Synthesis Focus Center

Prof. Kang Wang

The University of California at Los Angeles is the lead University for the Center for Functional Engineered Nano Architectonics (FENA) and Professor Kang Wang the center director. This center will research into critical nanomaterials and process challenges that address the core problems of nanoscale device technology. FENA will examine novel nanoscale materials and structures, with potential to be incorporated in devices and architectures of the future

UC-Berkeley

- Caltech
- CMU
- Ga Tech
- Michigan
- MIT
- Penn State
- Princeton
- Purdue
- Stanford
- UCLA
- UCSB
- UC SC
- UCSD
- UIUC
- U T Austin

CMU

- Columbia
- Cornell
- Ga Tech
- MIT
- Stanford
- UC-Berkeley
- UCLA
- UCSD
- U. Florida
- UIUC
- U Washington

Georgia Tech

- CMU
- Cornell
- MIT
- NC State
- RPI
- Stanford
- U at Albany
- UCBerkeley
- UCSB
- U . Central Florida
- UT Austin

MIT

- Caltech
- Cornell
- NC State
- Penn State
- Princeton
- Purdue
- Stanford
- U at Albany
- UC Berkeley
- UCLA
- UC SB
- U Florida
- U Maryland
- UT Austin
- U Virginia

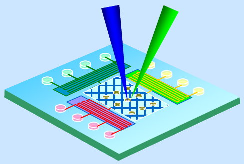
UC-Los Angeles

- Arizona State
- Caltech
- MIT
- NC State U
- UC Berkeley
- UCLA
- UC Riverside
- U at Stony Brook
- UCSB
- U Minnesota
- USC

MEMS S&T Initiative

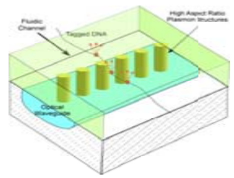
BioMEMS

Microfluidic Processors



UC Irvine

Biosensors



Harvard

Functionalized Surfaces

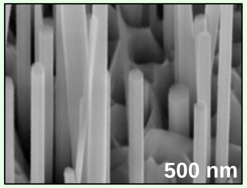
Cornell

Common Issues

- Surfaces
- Interfaces
- Reliability
- Scaling
- Materials
- Fabrication
- Modeling
- Nanostructures

Materials & Fabrication

Nanowire Sensors

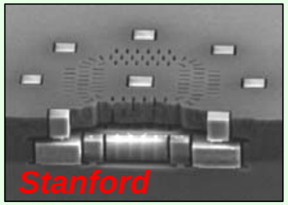


Colorado

Non-lithographic Fabrication

MIT

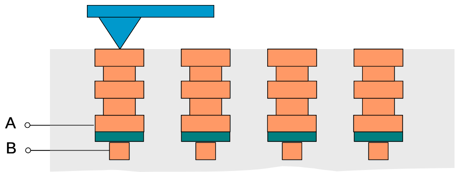
Materials Interfaces



Stanford

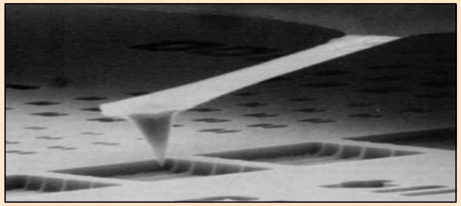
Systems/ Modeling

Self-Configuring ICs



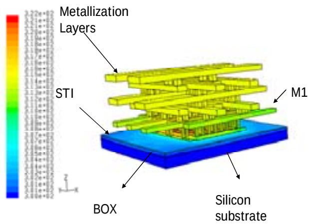
Carnegie Mellon

Nano Probes



Caltech

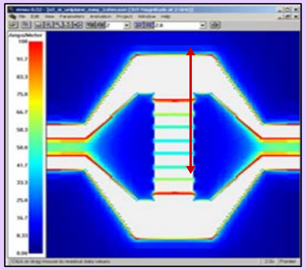
Multi-Physics Modeling



Illinois

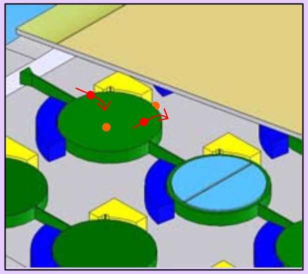
RF MEMS

Reliability Physics



UC San Diego

RF Scaling



UC Berkeley

Young Faculty Award

To encourage greater communication and participation by young investigators in DARPA/MTO sponsored research

DARPA MTO Young Faculty Award Seedling program

Purpose: To introduce young faculty investigators at the assistant professor level to DARPA funding and provide venue for new ideas through the release a targeted RA soliciting new ideas. Approximately 10 best ideas would be funded at the seedling level.

DARPA MTO YFA Workshop

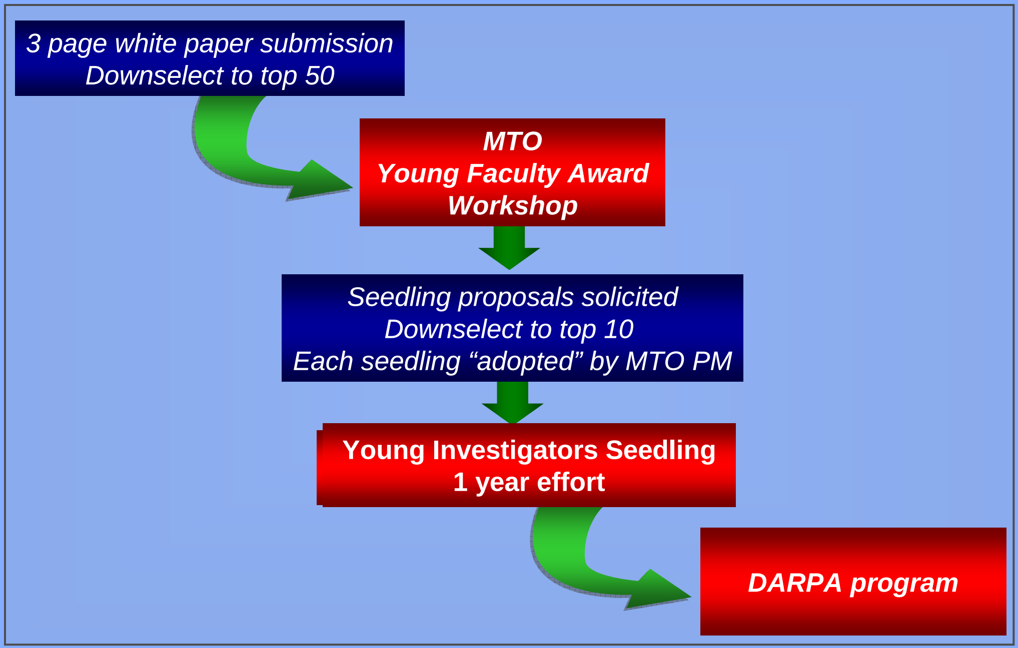
Purpose: To enable mutual education of young faculty researchers and PMs.

- DARPA culture and procedures
- Novel ideas by young researchers

Attendance based on evaluation of white-paper

Workshop will include DARPA/MTO overview, introduction to PMs and their interests, discussion of how to succeed at DARPA (culture, logistics, teaming, proposals), sidebars, session of short Government-only proposal pitch and evaluation.

All DARPA presented material would be publicly available at the end of the workshop.



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Summary

- DARPA is committed to delivering technology innovation for the Department of Defense.
- Microsystems technology continues to be a key enabler for new system capability.
- Engage with DARPA PM’s to define the future of Microsystems research.
- Microsystems Technology Symposium, March 5-7, 2007, San Jose, CA.

Questions?